Monitoring Priorities and Gaps

Puget Sound Ecosystem Monitoring Program Toxics Workgroup

Revised Draft

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1 Executive Summary

The purpose of this document is to present the monitoring priorities and gaps related to toxic contaminants in Puget Sound as determined by the Puget Sound Ecosystem Monitoring Program (PSEMP) Toxics Workgroup (TWG). The focus of this December 2013 document is on measures of the biophysical condition and human health within Puget Sound. Gaps and priorities related to monitoring of ecosystem pressures and recovery strategies and actions are not addressed.

The prioritization exercise relied on an ecosystem framework that dissects the ecosystem into domains, components, essential ecological attributes, and key ecosystems attributes (KEAs), which collectively describe the biophysical condition of the ecosystem. Following Biedenweg et al. (in prep) and O'Neill et al. (in prep) we applied this framework to the biophysical condition and human well-being dimensions of the ecosystem. The ecosystem framework was used as an organizational tool to determine priorities and gaps in toxics monitoring in Puget Sound based on the premise that, in order to understand biophysical condition and human well-being, the state of KEAs must be known. Therefore, priority considerations are monitoring efforts that characterize the KEAs.

A specific list of top five priorities for monitoring was identified following an extensive effort. The priorities are:

1. Monitoring activities to support the **Toxics in Fish Vital Sign**
2. Special studies under a **Biological Observation System.**
   First Priority is to evaluate magnitude and health effects of Chemicals of Emerging Concern (CECs) in/on Puget Sound biota
3. Monitoring of **Toxics in Harbor Seals** (or other marine mammals)
4. Monitoring of **Toxics in Mussels**
5. Enhancements to **Marine Sediment Quality Vital Sign**

Several steps were taken in the development of the priorities list. Selecting priorities for the monitoring of toxics is complicated by the array of combinations of toxic compounds, aquatic and terrestrial organisms, and spatial and temporal considerations. In order to systematically consider the options, a set of matrices was created based on the organizational frameworks (see Figures 3, 4, and 5), with exposure scenarios illustrated in the conceptual models (Appendix C). The PSEMP TWG was then surveyed (see Appendix F) to rate the importance of each scenario with regard to characterizing the status and trends of the ecosystem. The survey was used to identify priorities and informed the creation of a specific list of the top five priorities for monitoring.

Following the survey work, the TWG developed a set of priority statements, which are broader than the Top Five list. These are:

- Toxics in Biota: Monitoring 1) PAHs, 2) chlorinated persistent compounds (PCBs, dioxins/furans, OC pesticides), 3) flame retardants in selected marine organisms, and 4) contaminants of emerging concern is a priority. Monitoring for the Toxics in Fish Vital Sign is a priority. Key indicator species include marine macrofaunal epibenthic invertebrates (including shellfish, and mussels in

particular), marine benthic fish, marine pelagic fish, juvenile salmon, and marine mammals (specifically, harbor seals). Monitoring toxics in freshwater organisms was also identified as a gap during a workgroup meeting, but considered a lower priority than marine biota, and is therefore excluded from the gaps and priorities sections.

- Impacts of Toxics on Biota: Monitoring sub-lethal effects (e.g., endocrine disruption, vitellogenin induction, etc.) in marine vertebrates and freshwater fish and amphibians is a priority. Monitoring for toxics in biota according to the Toxics in Fish Vital Sign is also a priority, as is monitoring for marine infaunal benthic invertebrates and freshwater invertebrate community condition.
- Toxics in Marine Water and Sediments: Monitoring of toxics in marine sediments is a priority, with emphasis on conditions in urban bays and in the central basin and south Puget Sound. Monitoring toxics in marine water was not considered a priority.
- Toxics in Freshwater: The highest priority in this component is monitoring current-use pesticides in agricultural and urban streams, though priority ratings were low compared to other components and are not included in the gaps and priorities sections of this document.

The top two toxic-related studies for Puget Sound were also identified, resulting in a list of 32 suggestions (Appendix F). The TWG then voted to prioritize the 32 suggestions. Study ideas with similar themes were grouped and the votes totaled for each group. Results indicated that the top priorities from this list were:

- Monitoring of Contaminants of Emerging Concern in the environment and biota, and
- Studying the impacts of toxics on biota (e.g., sublethal, multiple stressor, community composition).

Results also highlight interest by a number of TWG members in (1) the bioaccumulation and occurrence of toxics in fish, clams, crabs and other marine species consumed by humans and (2) monitoring of current use pesticides in freshwater.

The TWG would like to emphasize that there remains a degree of subjectivity associated with the interpretation of the prioritization survey results. A discussion is included in the body of the report.

An evaluation of priority gaps was also performed. Monitoring gaps were determined by comparing the results of the prioritization effort with the toxics monitoring inventory.

The TWG would like to emphasize two key principles: 1) monitoring of condition requires sufficient data to track status and trends, identify emerging problems, and address Vital Signs, and 2) a functional monitoring program requires investment in support infrastructure such as data management tools (e.g., providing electronic data access), updating sample collection protocols, and the development of new analytical methods.

Finally, though more work is required, the effort to date represents a great deal of progress to identify a clear list of toxics-related monitoring priorities, The final parsing would be dependent on distinctly defined monitoring goals and objectives.

2 Introduction

The purpose of this document is to present the approach and rationale utilized by the Puget Sound Ecosystem Monitoring Program (PSEMP) Toxics Workgroup (TWG) to evaluate monitoring data, priorities, and gaps related to toxics in Puget Sound. The intent of the exercise is to coordinate monitoring of toxic chemical contamination and associated impacts to the Puget Sound ecosystem.

A comprehensive strategy that will guide, inform, and coordinate toxic monitoring efforts across Puget Sound requires various approaches. These include monitoring:

- ecosystem condition,
- toxics-related pressures,
- effectiveness of toxic-related remedial strategies and near-term actions as described in the Action Agenda, and
- as mandated by the legislature.

Identification of priority monitoring for each of these categories will take considerable time; the TWG has taken a tiered approach. The first tier is to evaluate toxics monitoring necessary to assess the status and trends of Puget Sound's biotic and abiotic condition. Priorities related to the other types of monitoring will be completed at a future date.

In addition to prioritizing the status and trends monitoring programs, an effort is needed to prioritize studies necessary to understand fate and transport of toxics within the Puget Sound ecosystem. Broadly speaking, recommended studies fall into two major categories:

1) diagnostic, and
2) modeling and integration.

Diagnostic studies establish effects thresholds associated with contaminant exposure, allow inter-laboratory comparisons, and develop sampling protocols and methodologies. Modeling and integration studies inform on fate and transport processes, bioaccumulation, and exposure impacts to populations, communities, and ecosystems.

To guide the monitoring prioritization process, the TWG used an ecosystem framework (O'Neill et al., in prep; Biedenweg et al, in prep; Figure 1). The ecosystem framework is based on a generalized causal network that links the assessments of ecological condition and human well-being in Puget Sound with strategies to reduce toxic pressures and toxic effect on Puget Sound ecosystem health. Assessing a complete array of condition and pressure indicators can aid the analysis of the causal mechanism underlying compromised ecosystem condition. A biophysical framework proposed by USEPA (2002) guided the selection of indicators of biophysical condition for Puget Sound. Use of this framework ensures that a sufficiently large set of attributes of structure (i.e., pattern) and processes are selected to fully assess the biophysical condition. The EPA framework was recommended for consideration by the Puget Sound Partnership (PSP; O'Neill et al. 2008) and the Washington State Academy of Sciences (Orians et al. 2012).

Further, the framework guides identification of key ecological attributes (KEAs) for the particular topic area or region of interest. The TWG identified KEAs for contaminants in Puget Sound (Figures 3, 4, and 5) and an inventory of monitoring activities (Appendix A) was mapped onto the resulting ecosystem framework.

In late 2012 and early 2013, a series of conceptual models were designed to visualize the pathways of contaminants from their sources to different domains in the ecosystem, and finally to the biological components (Appendix C). The models complement the biophysical ecosystem framework (Figure 1) and serve to demonstrate the linkages between various species and sources of contaminants so as to ensure that gaps are identified in monitoring activities. They also highlight what components of each domain the TWG is focusing on and detail the species of interest in food webs. Species groupings used in the survey to determine gaps were generated in these models.

Four models were developed:

a. Movement of bioaccumulative compounds from their source to different ecosystem domains, freshwater and marine food webs, and human systems.

b. Movement of PCBs through a marine food web.

c. Movement of PAHs through a marine food web.

d. Sources of contaminants, the movement through marine and freshwater food webs to human systems, and resulting pressures.

Gaps and prioritization work performed by the TWG proceeded from an inventory of monitoring activities (Appendix A), an evaluation of the monitoring gaps specifically related to the Puget Sound Partnership (PSP) Vital Sign indicators (Appendix B), a survey of TWG members' ratings of the importance of specific status and trend monitoring topics and toxics-related studies (Appendix F), and an evaluation of current monitoring efforts and monitoring gaps related to highly-rated monitoring topics.

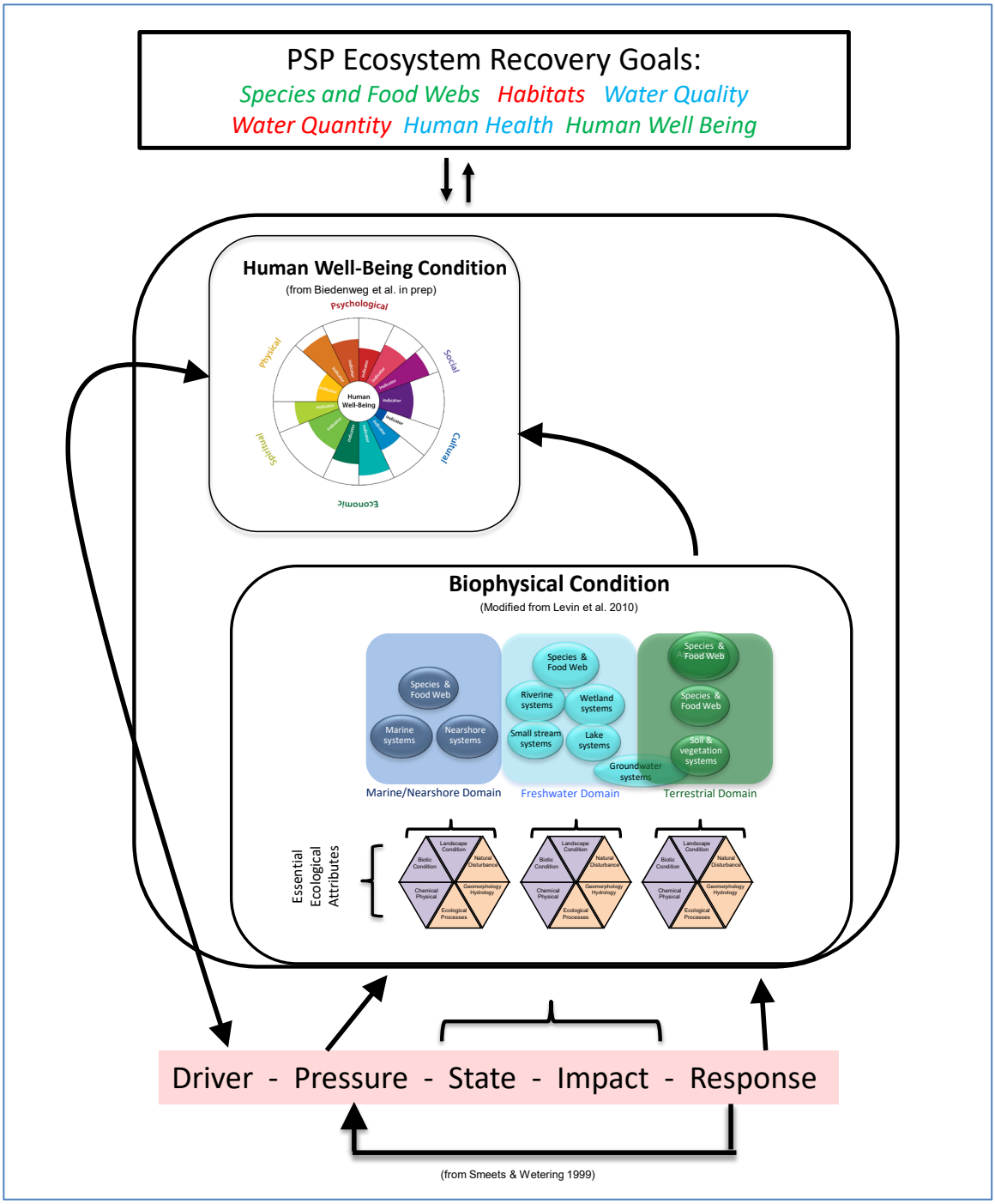

Figure 1. The Puget Sound ecosystem recovery framework (O'Neill et al., in prep). This framework is used with conceptual models as a tool to evaluate monitoring priorities related to the assessment of toxic chemical contamination and harm in the Puget Sound ecosystem.

3 Framework for Assessing Toxic Chemical Effects on the Biophysical Condition of the Puget Sound Ecosystem

As a PSEMP workgroup the TWG focused on the synthesis of scientific information to assess the risks and impacts of toxic chemicals on the biophysical condition of Puget Sound, including human health. To assist in the evaluation of monitoring gaps and priorities the TWG adopted a focused biophysical framework, which is part of the overarching ecosystems recovery framework described above (Figure 1). The biophysical framework divides the system into macro-scale domains, each domain separated into functional components (Figure 2(A)). Each of the biophysical condition components can be described through a set of essential ecosystem attributes (EEAs (EPA 2002)). As the focus is on toxic chemicals, not all components and EEAs are applicable. A modified biophysical framework indicating the focal components and EEAs is presented in Figure 2(B). Although it is recognized that toxic contamination of the terrestrial system may pose risks to terrestrial species and food webs, the evaluation includes air and soil components of the terrestrial domain only as they might affect conditions and and human health risks in aquatic systems and human well-being. As such, there is no evaluation of the biotic condition of the terrestrial domain from this workgroup.

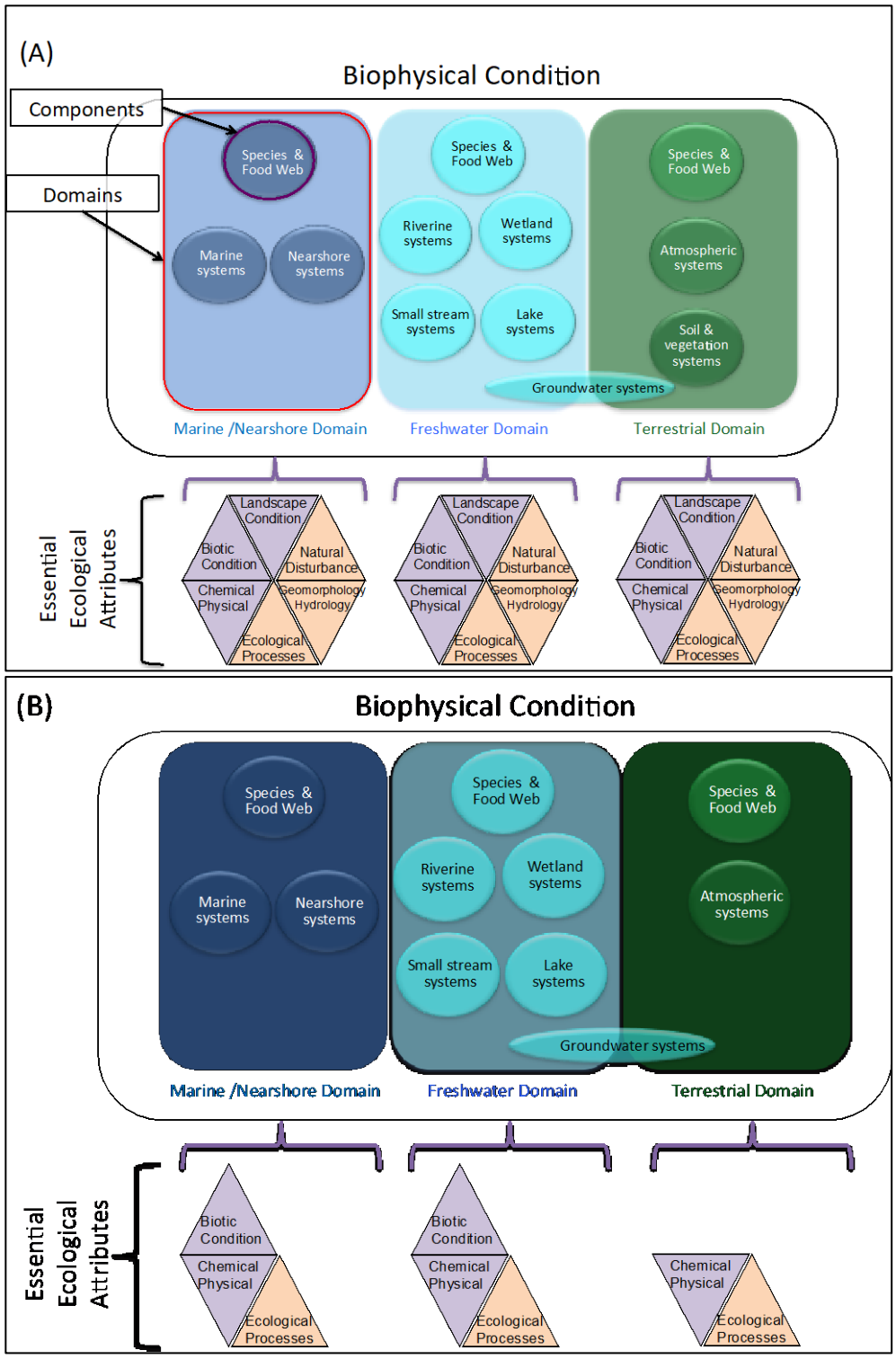

Figure 2. (A) The complete biophysical condition framework and (B) the subset of the biophysical condition framework of interest to the PSEMP TWG. The scope of concern extends to all domains and all components, except terrestrial species and food webs. Only three of the six essential ecosystem attributes (EPA 2002) are included. The condition of attributes of each component will be described through monitoring data.

As shown in Figure 2(B), toxic contamination in the marine/nearshore and freshwater domains of the Puget Sound ecosystem relates to three EEAs: biotic condition, chemical and physical characteristics, and ecological processes (O'Neill et al., in prep; EPA 2002). Toxic contamination in the terrestrial domain relates only to the chemical and physical characteristics and ecological process. Detailed frameworks for each of these EEAs are presented in Sections 3.1, 3.2, and 3.3.

The focus of this effort does not extend to the remaining EPA-defined EEAs of: (a) landscape condition (i.e., extent of systems or habitat types, landscape composition, and landscape pattern and structure); (b) natural disturbance regimes; or (c) hydrology and geomorphology (i.e., surface and groundwater flows, dynamic structural characteristics, and sediment and material transport). However, the conceptual models do include links to landscape condition (e.g., land cover and land use) and hydrology (e.g., inputs from stormwater) because this can be an influencing factor for the TWG's monitoring activities. Other PSEMP topic groups (i.e., Freshwater, Marine Waters, etc.) and local experts will provide information on those ecosystem attributes with links to help us understand and communicate about sources of toxic chemical stress and transport pathways.

A hierarchical approach was taken to describe biophysical condition. As shown in Figures 2(A) and 2(B), the EEAs broadly describe the state and condition of the individual components. In order to describe the EEAs, KEAs were selected. As such, in order to understand the state and condition of the EEAs, the state and condition of the KEAs must be known. This hierarchical ecosystem framework approach follows EPA (2002), Levin et al. (2010), Kershner et al. (2011), and James et al. (2012). These authors and a Washington State Academy of Sciences review panel (Orians et al. 2012) recommend the use of a hierarchical framework to describe the rationale for developing a comprehensive monitoring program.

KEAs were selected by identifying attribute categories of interest for each type of component (i.e., species and food webs and systems). For species and food web components, KEAs were defined by biotic condition (Section 3.1). For systems components, KEAs were defined in the chemical and physical characteristics and ecological processes attribute categories (Sections 3.2 and 3.3, respectively). The KEAs are shown in Figures 3, 4, and 5. It is expected that KEA information will also be useful to assess progress toward achieving ecosystem recovery goals established by the PSP and others.

3.1 Biotic Condition

The EPA (2002) describes biotic condition with the following attribute categories:

- Ecosystem and community – e.g., community extent, composition, and dynamics; trophic structure; physical structure.
- Species and populations – e.g., population size, structure, and dynamics; genetic diversity; habitat suitability for focal species.
- Organism – e.g., physiological status; symptoms of disease or trauma; signs of disease.

Based on those attribute categories, three biotic condition KEAs related to toxic chemical contamination were selected:

- Benthic community condition
- Presence of toxic agents in organisms
- Organism response to toxic stress

These KEAs provide both individual and community measures of biotic condition. Benthic community condition is a measure that describes the composition of communities of organisms dwelling in or on sediment surfaces, and may be directly or indirectly related to toxics. The presence of toxic agents in organisms and organism response to toxic stress are measures of biotic condition at the individual level that are directly linked to toxics.

The relationship between biotic condition, domains, components, and the KEAs is shown in Figure 3. These KEAs were selected based on recommendations for measuring biological endpoints related to exposure and effects (Johnson et al. 2010) and conceptual model notations that measures of ecosystem state related to toxic contaminants include contaminant exposure, sediment quality triad, and measures of toxicopathic disease (Pearson et al. 2010). We extended the suggestions developed for marine and nearshore biota to freshwater biota, as these attributes will also be important to impacts on freshwater species and food webs.

We acknowledge that toxic chemicals in Puget Sound soil, air, water, and prey may affect terrestrial species, but have elected to focus the assessment of biotic condition to aquatic species.

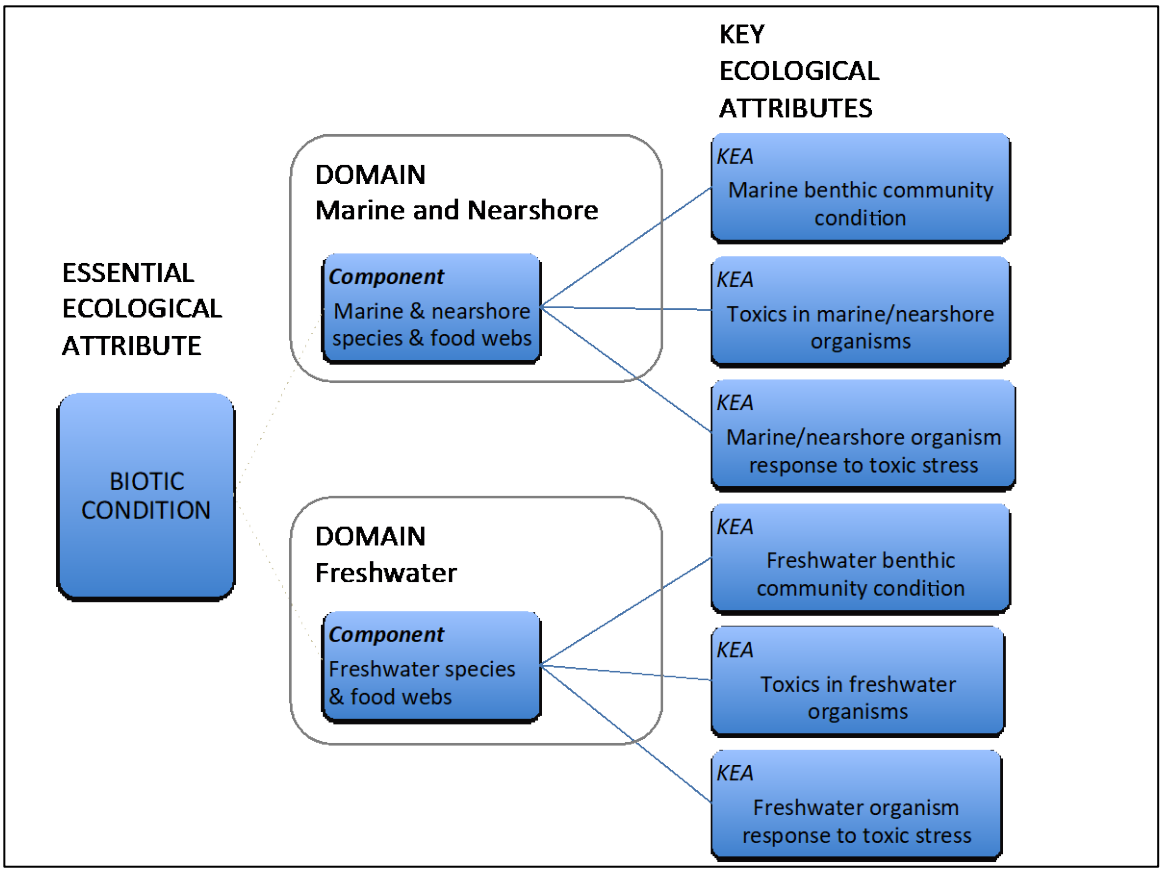

Figure 3. KEAs of biotic condition selected by the TWG to assess the potential impact of toxics on species and food webs in marine and nearshore, and freshwater domains. Note that KEAs include the biotic condition at the community level as well as the individual level.

3.2 Chemical and Physical Characteristics of Aquatic and Terrestrial Systems

The EPA (2002) describes chemical and physical characteristics with the following attribute categories:

- Concentrations of nutrients – e.g., nitrogen, phosphorus, other nutrients.
- Concentrations of trace inorganic and organic chemicals – e.g., metals, other trace elements, organic compounds.
- Other chemical parameters – e.g., pH, redox potential, salinity, organic content.
- Physical parameters of soil and sediment – e.g., temperature, texture, porosity, bulk density, profile, mineralogy.
- Physical parameters of air and water – e.g., temperature, wind velocity, relative humidity, UV radiation, concentrations of particulates, turbidity.

KEAs were selected based on the above attribute categories (Figure 4). Each KEA addresses either organic or inorganic chemicals in one type of environmental media. We have not identified KEAs for toxic chemical concentrations in marine water. Data are available to describe many chemicals in marine water, which can be compared to marine water quality criteria.

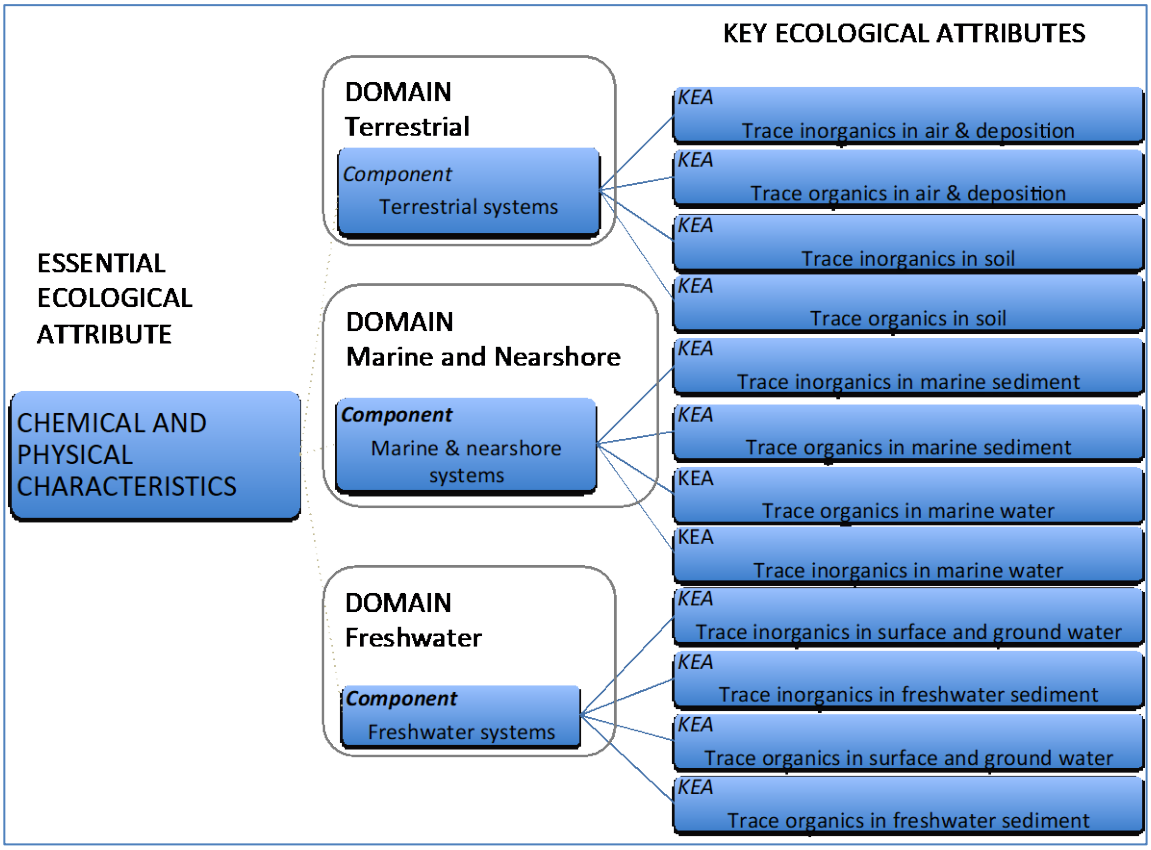

Figure 4. KEAs selected by the TWG to characterize toxics-related chemical and physical characteristics of Puget Sound aquatic and terrestrial systems. Various components of the freshwater domain (e.g., lakes, small streams, etc.) have been compressed into one grouping for clarity.

3.3 Ecological Processes in Aquatic Systems

The EPA (2002) describes ecological processes with the following attribute categories:

- Energy flow – e.g., primary production, net ecosystem production, growth efficiency.
- Material flow – e.g., organic carbon cycling, nitrogen and phosphorus cycling, other nutrient cycling.

Our assessment of ecological processes does not include measures of energy flow.

Processes relevant to toxics monitoring include chemical sources, fate, transport, metabolism, and accumulation. These processes are included as KEAs in marine and freshwater domains (Figure 5).

It is acknowledged that fate and transport information for compounds may be obtained through focused studies and investigations that may not necessarily include monitoring activities. However, it is often critical to evaluate processes and populate modeling

activities through data obtained with environmental monitoring. As such, monitoring can support the evaluation of important ecological processes. We focus on identifying these monitoring activities.

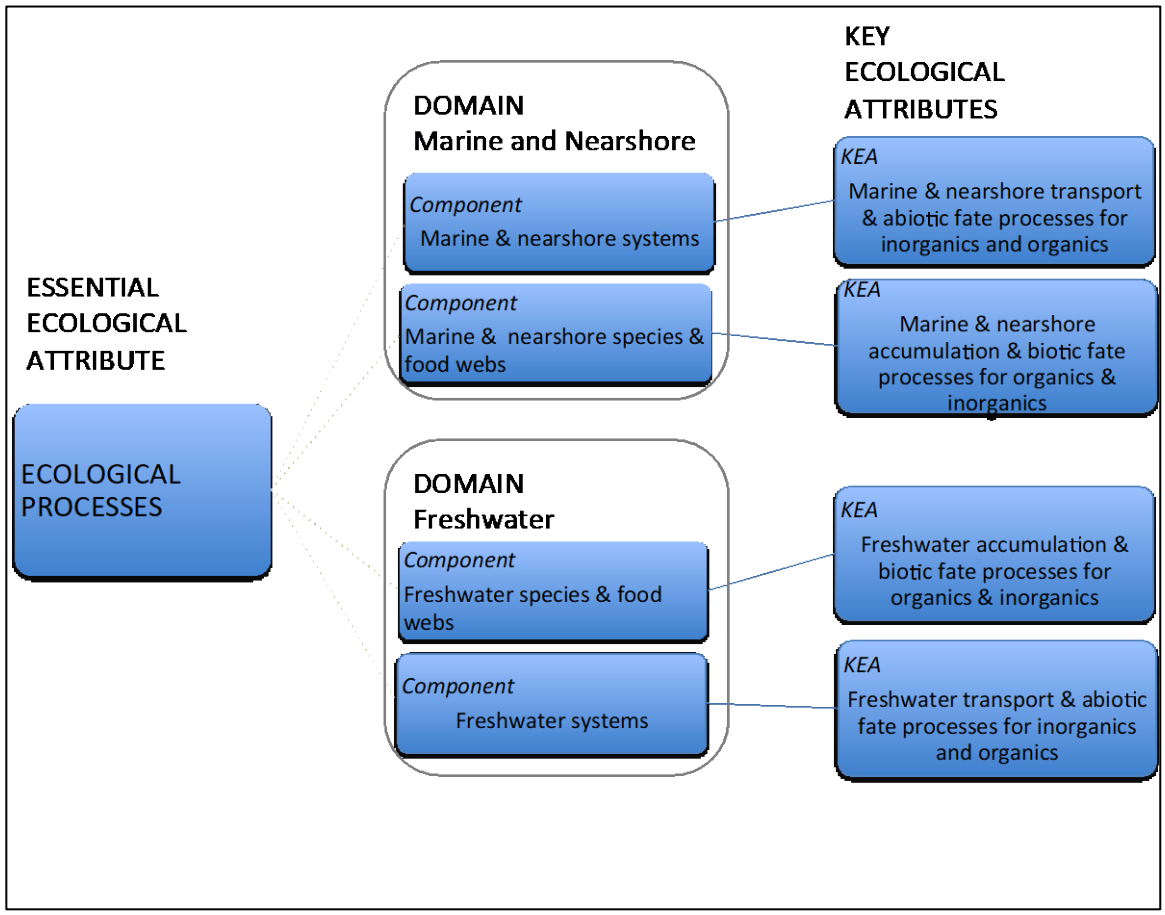

Figure 5. KEAs selected by the TWG to characterize ecological processes in freshwater and the marine and nearshore domains of Puget Sound. The ecological processes of concern fall under the attribute category of material flows.

3.4 Human Well-Being

Human well-being can be described in a similar hierarchical approach as biophysical condition, with analogous domains and components (Figure 1). Components of the human well-being framework include physical, cultural, spiritual, social, and economic well-being.

3.4.1 Human Health

In alignment with the goals established for the PSP, we use the term 'human health' as a synonym for physical well-being. There are two components of primary concern to the TWG related to human health: 1) human health risks from consuming contaminated fish and shellfish, and 2) exposure to contaminated water, soil, and air. A number of the

KEAs detailed above for biophysical condition also characterize toxic-related human health concerns:

- Biotic condition KEAs about toxics in organisms can be used to inform human health risks from exposure from seafood consumption.
- Chemical and physical characteristics KEAs about contamination of water, soil, and air can inform on human health risks from ingestion, dermal, and inhalation exposures.

Additional attributes, related to the biotic condition of humans, would support a more complete characterization of toxic chemical-related human health risks:

- Incidence of toxic-related illness from Puget Sound ecosystem exposures (e.g., immune function, developmental impacts)
- Metrics of human exposure to toxic contamination of the Puget Sound ecosystem (e.g., blood mercury levels in fish consumers, or PCBs in blood)

The TWG discussed these attributes but has not identified them as KEAs and they were not explicitly addressed in our prioritization process.

3.4.2 Other Components of Human Well-being

The TWG also briefly discussed the attributes of cultural, spiritual, social, and economic aspects of human well-being:

- Subsistence harvesting and consuming of fish and shellfish (e.g., opportunities afforded and restrictions)
- Ceremonial harvesting and consuming of fish and shellfish (e.g., opportunities afforded and restrictions)
- Recreational harvesting and consuming of fish and shellfish (e.g., opportunities afforded and restrictions)
- Commercial harvesting of fish and shellfish (e.g., opportunities afforded and restrictions)
- Other cultural, spiritual, and recreational activities affected by toxic chemical contamination (e.g., restricted access or posted warnings related to contaminated sites)

As this point, the TWG has not identified these as KEAs, and they were not addressed in our prioritization process.

4 TWG Status and Trend Monitoring - Priorities

The focused framework (Figure 2(B)) and KEAs (Figures 3, 4, and 5) supported the identification of monitoring priorities for the TWG. Based on the framework logic, in order to understand toxic chemical contamination and associated impacts, it is necessary to have information on each of the KEAs. Our monitoring priorities focus on efforts that provide information on the condition of these KEAs.

A challenge of prioritizing monitoring activities associated with toxic compounds in the environment is the vast array of exposure scenarios, which include the range of (1) potentially toxic compounds and/or compound classes, (2) biological receptors, (3) spatial variation, and (4) temporal variation. In order to systematically consider potential combinations, a set of matrices was created based on the EEA organizational frameworks shown in Figures 3, 4, and 5, with exposure scenarios illustrated in the conceptual models (Appendix C). The TWG was surveyed to rate the importance of pairings with regard to characterizing the condition of the ecosystem. An additional survey question queried respondents to identify their top two priority studies related to understanding the biotic condition of Puget Sound. Thirty-two responses were received. In a follow up exercise, TWG members were requested to identify the highest priority amongst the thirty-two listed. Results were summarized by absolute number of votes and were also ranked by subject group, as many of the study ideas were similar. The survey and results are included in Appendix F, and summarized in sections 4.2, 4.3, 4.4, and 4.5.

Finally, the top five priorities were identified at the request of the PSEMP Steering Committee based on the results of the survey work and extensive workgroup review and discussion. Results are summarized in section 4.1.

4.1 Top Five Priorities

The top five priorities for toxics-related monitoring in the Puget Sound are described very briefly in the following sections.

4.1.1 Monitoring activities to support the Toxics in Fish Vital Sign

This Vital Sign integrates multiple contaminant classes for key indicator species. The program is currently underfunded as a result of budget reductions. Funding needs to be reinstated and bolstered to address the full range of risk driver chemicals and indicator species identified in PSP's recovery target for this Vital Sign.

Estimated cost: $870,600 per biennium in addition to existing base funding of $636,711 per biennium.

4.1.2 Special studies under a Biological Observation System.

Establish a routine monitoring and diagnostic program to identify exposures to toxics and associated adverse effects in the Puget Sound ecosystem. This is consistent with the WDFW/NOAA-NWFSC Toxics-Focused Biological Observing System (TBiOS).

This program will include both field sampling and laboratory research to address issues such as: indicator development, analytical method development, establishing cause-and-effect relationships between exposure and biological alterations, and investigating threshold effect concentrations. Focus studies will also investigate specific issues related to toxic contaminants, e.g., survival, growth, reproduction, disease resistance, and behavior that cannot be obtained from existing monitoring programs.

The highest priority element of this effort is to evaluate the extent, magnitude, and health effects of Chemicals of Emerging Concern (CECs) in/on Puget Sound biota.

Estimated Cost: $453,000 per biennium

4.1.3 Monitoring of Toxics in Harbor Seals (or other marine mammals)

No regular monitoring of toxics in marine mammals currently exists in Puget Sound. This is also a stated monitoring priority of the PSEMP Marine Mammals workgroup.

Estimated Cost: $150k every 3-5 years for contaminants at five sites

4.1.4 Monitoring of Toxics in Mussels

This is also a stated priority of Stormwater workgroup. Monitoring for toxics in mussels within the Urban Growth Area (UGA) boundaries is a selected study for the participants in the Regional Stormwater Monitoring Program. This program will last one year. Monitoring for toxics in mussels outside the UGAs is a listed PSEMP priority for this current exercise.

Estimated Cost: $500,000 per biennium to monitor 100 sites

4.1.5 Enhancements to Marine Sediment Quality Vital Sign

Basic Vital Signs monitoring is currently occurring. It is a priority to maintain the existing program. There are gaps in the program including a lack on monitoring for CECs and limited monitoring in embayments and in the nearshore sediments. However, the current, highest priority is:

1) Re-establishment of in-house benthic invertebrate taxonomy conducted by Ecology's Marine Sediment Monitoring Team to maintain consistency in community structure data – Due to declining number of regional contract taxonomists, this is required to maintain consistent, accurate species-level identification of benthic invertebrates collected for the PSEMP Sediment Component.

Estimated cost: $482,000 per biennium to hire three experienced taxonomists at an Environmental Specialist 4 level.

4.2 Biotic Condition - Priorities

The survey was designed to capture the TWG priorities of biotic condition related to monitoring Toxics in Marine/Nearshore Organisms, Toxics in Freshwater Organisms, Marine/Nearshore Organism Response to Toxics Stress, and Freshwater Organism Response to Toxic Stress (see Figure 3). Two questions specifically addressed these KEAs.

With regard to toxics in organisms, respondents were requested to rate the importance of monitoring specific species-groups/contaminant-group combinations. Results of the survey indicated that there were several important combinations that should be considered priorities for monitoring the biophysical condition of Puget Sound: 1) PAHs, 2), chlorinated persistent compounds (PCBs, dioxins/furans, OC pesticides), and 3) flame retardants in marine organisms (Appendix F). Key indicator species included marine macrofaunal epibenthic invertebrates (including shellfish), marine benthic fish,

marine pelagic fish, juvenile salmon, and marine mammals. Monitoring toxics in freshwater organisms was considered a lower priority.

With regard to organism response to toxic stress, respondents were requested to rate the importance of monitoring specific combinations of species groups and potential responses at both the individual and community level. Results indicated that monitoring sub-lethal effects (e.g., endocrine disruption, vitellogenin induction, etc.) in marine organisms (primarily fish) and freshwater fish is a priority. Additionally, with regard to the effects of toxic stress on benthic community condition, measuring the condition of marine infaunal and freshwater benthic invertebrate communities were ranked as the highest priority.

Finally, the answers to the question related to study ideas clearly indicated that investigating toxics impacts on biota (e.g., sublethal effects monitoring in major trophic levels, effects of stormwater on biotic condition, impacts of Chemicals of Emerging Concern, etc.) was a priority.

4.2.1 Expected collaborations across PSEMP

We have not identified any KEAs that address population-level response to toxic chemical exposure and harm. We anticipate collaborating with the Forage Fish, Salmonid, and Modeling workgroups to develop approaches to characterize population-level effects from toxic chemicals.

We also plan to collaborate with the Stormwater, Freshwater, and Modeling workgroups to develop approaches to characterizing community-level effects from toxic chemicals in freshwater (e.g., understanding toxic chemical contributions to impairments in benthic invertebrate biotic index).

4.3 Chemical and Physical Characteristics - Priorities

The survey was designed to capture priority rankings for the following KEAs: Trace Inorganics in Marine Sediment, Trace Organics in Marine Sediment, Trace Inorganics in Surface- and Ground-water, Trace Organics in Surface- and Ground-water, Trace Inorganics in Freshwater Sediments, Trace Organics in Freshwater Sediments, Trace Inorganics in Marine Water, and Trace Organics in Marine Water.

Respondents were requested to rate the importance of several compound classes in different media (freshwater, marine sediments, etc.) in various locations throughout Puget Sound. Results indicated that toxics monitoring in marine sediments is a priority, particularly in urban bays. Chlorinated persistent compounds (PCB, dioxins/furans, organochlorine pesticides, etc.) in sediment was the compound group which consistently received the highest rating. Monitoring toxics in marine water was not considered a priority.

With regard to Toxics in Freshwater and Sediments, the highest priority was monitoring current-use pesticides in streams, though priority ratings were generally lower than for marine systems (see Appendix F).

Results of the survey question to identify important studies clearly identified Chemicals

of Emerging Concern (CECs; e.g., extent and magnitude of CECs in marine sediments/urban bays/streams and rivers, etc.) as a priority.

4.3.1 Expected collaborations across PSEMP

Although we have not identified physical parameters and conventional parameters as KEAs, we expect that assessment of toxic contamination and harm at both the organism and community level will benefit from information on: nutrient concentrations, dissolved oxygen, pH, dissolved organic carbon, alkalinity, hardness, water temperature, total suspended solids, and turbidity. Chemical toxicity is often dependent on water conditions represented by conventional parameters. We expect to collaborate with the Marine Waters, Freshwater, and Stormwater workgroups to ensure that monitoring of these parameters supports assessment of toxic chemical contamination and harms.

4.4 Ecological Processes - Priorities

Toxics-related ecological processes relate to the fate and transport processes that impact distribution and exposure of compounds. Survey matrices did not directly identify key monitoring priorities related to ecological processes. This exercise indicated that fate and transport modeling was an important consideration, though not as highly rated as other study ideas.

It should be noted that many of the priority monitoring activities described in Sections 4.1, 4.2, and 4.3 were identified as such due to the fact that they provided information necessary to evaluate fate and transport processes, as revealed during discussions on survey results during the TWG meetings.

4.4.1 Expected collaborations across PSEMP

Our expected collaborations related to fate, transport, accumulation, and adverse effects are similar to those discussed above related to population-level assessments of biotic condition. We anticipate collaborating with most other PSEMP workgroups on linked abiotic-biotic models integrating sources of stress across the landscape with contamination and harm in freshwater, nearshore, and marine domains.

4.5 Human Health

As described above, the survey was designed to identify monitoring priorities related to characterizing the status and trends associated with biophysical condition and not specifically human well-being or human health. As demonstrated, however, many potential KEAs for human health are addressed by information associated with the KEAs of biotic condition and chemical and physical characteristics (see Section 3.4). Therefore, from a human health perspective, there is important and relevant data that would be available from the monitoring priorities identified above.

The most important exposure route to humans for Puget Sound toxics is through consumption of seafood. Many seafood consumption exposures to humans are covered by the priorities identified in Appendix F, although a few gaps remain related to

species, locations, and some chemicals. Our priorities may also provide relevant information to characterize risks from other routes of humans to toxic chemical contaminants in the Puget Sound ecosystem.

4.5.1 Human Health – Toxics in Biota

With specific regard to toxics in biota, the priorities cover most of the human health concerns related to fish and shellfish consumption. However, toxics in macroalgae has been identified as a possible exposure route. There is a lack of information on whether harvesting and consuming seaweed is a concern for humans. Information on CECs in freshwater fish is also high priority from a human health perspective as clearly demonstrated in the survey responses. There are also potential concerns about specific metals in benthic organisms; specifically arsenic speciation in shellfish and cadmium in oysters. Although survey results indicated some support for this monitoring effort (i.e., other metals in marine macrofaunal epibenthic invertebrates), the survey approach did not allow for such specific identification of monitoring priorities.

4.5.2 Human Health – Toxics in Freshwater and Sediments

With specific regard to toxics in freshwater and sediments, there is a clear justification for monitoring groundwater quality, particularly in areas that lack centralized water supply systems and which obtain drinking water from wells. Groundwater supplies are neither tracked nor monitored for listed contaminants unless specifically identified by the Department of Ecology in association with a contaminated site. Current use pesticides in groundwater, lakes, and streams pose the greatest risk to private water supplies as validated by data collected from our public water sources. Groundwater quality was not identified as a priority for understanding chemical and physical characteristics of Puget Sound.

4.5.3 Human Health – Toxics in Marine Water and Sediment, Air, and Soil

Our survey indicated much greater support for characterizing toxic contamination of marine sediment compared to marine water. Marine sediment contamination may contribute to human health risks from dermal and incidental ingestion exposures, but it is not clear that these exposure pathways pose significant risks in the Puget Sound ecosystem or that the characterization of marine sediments to assess biophysical condition would address concerns about these exposures (e.g., sampling locations would not coincide with areas of potential human contact exposures).

Our survey approach and, consequently, our results do not address contamination of air and soil in Puget Sound. Additional work by the TWG would be needed to understand if characterization of contamination in these media would emerge as a TWG priority.

4.6 Limitations to the Identification of Priorities

Priorities and gaps identified herein were largely based on survey results shown in Appendix F and are limited in their scope and range. Respondents were requested to focus specifically on priorities related to understanding the biophysical condition of

Puget Sound. A different focus may have lead to a different set of priorities, as illustrated in the discussion related to human health (see 4.4).

To further illustrate, survey results indicated that monitoring freshwater and sediments (Trace Inorganics in Surface- and Ground-water, Trace Organics in Surface- and Ground-water, Trace Inorganics in Freshwater Sediments, Trace Organics in Freshwater Sediments) was generally not a high priority. However, it is likely that freshwater, and particularly stormwater, entering the marine waters of Puget Sound is a significant source of contaminants. As such, from the perspective of source identification and correction, freshwater monitoring may be a priority. Priorities for objectives different than understanding condition of Puget Sound may differ that those reported herein.

Finally, the TWG wants to acknowledge that survey results may not be reflective of the priorities of individuals or individual programs. The results shown in Appendix F are summaries and average response scores. Obviously, individual responses may differ from these values.

5 General Priorities for Continued Monitoring and Priority Monitoring Gaps

The top five priorities (see section 4.1) are the TWG recommendations for toxics-related monitoring. However, a larger suite of important programs was identified during the prioritization process. This section presents the entire suite of important monitoring programs and gaps.

Priorities include:

- Results from the survey
- Results from the Top Five priorities document
- Vital Signs covered by the TWG
- Priority existing programs

In review, the TWG approached the prioritization effort through the following steps:

1. Selecting KEAs (Section 3)
2. Identifying monitoring priorities (Section 4)
3. Mapping the TWG monitoring priorities (Section 4) onto the selected KEAs
4. Mapping of the inventory of toxics monitoring activities (Appendices xx - xx) onto the monitoring priorities
5. Identifying priority gaps. Gaps were defined as priorities that were not covered, or were insufficiently covered, by existing monitoring programs.
6. Presenting Vital Signs gaps we identified previously (TWG 2013) as KEAs or aspects of KEAs to be monitored to address TWG monitoring priorities

Some additional notes on the process:

The results of step 3 are reflected in the organization of the survey as well as the presentation of the gaps (Tables 1-5).

In step 4, we mapped current monitoring activities (as captured in the TWG monitoring inventory) onto our selected KEAs and the subset of KEAs that reflect our monitoring priorities. This mapping is presented in Appendix G.

Priority existing programs were included in the tables. If these programs were eliminated they would become gaps.

Priority gaps were identified as situations where KEAs were not sufficiently characterized through current monitoring.

The gaps of the Vital Signs Gap Analysis (TWG 2013) are also included in the tables.

The gaps occur primarily in two EEA categories: Biotic Condition (Section 5.1) and Chemical and Physical Characteristics (Section 5.2). Gaps in Ecological Processes (Section 5.3) were not specifically addressed by the survey; however, the TWG identified gaps during a meeting. Human health gaps (Section 5.4) were not specifically addressed; however, toxics monitoring can provide information important in human health evaluations.

5.1 Biotic Condition – Gaps

We identify gaps in three KEAs related to toxic effects on biotic condition: community composition, toxics in biota, and effects in biota (Table 1, Table 2, and Table 3, respectively). We have identified gaps (or priorities for continued monitoring) related to macrofaunal epibenthic invertebrates and higher trophic levels. Priority gaps in characterizing biotic condition are primarily in the marine domain.

Table 1. Monitoring priorities, existing monitoring programs related to those priorities, and gaps for the KEAs associated with community composition. The KEAs and domains have been identified as priorities. Information includes existing monitoring programs that provide information on the KEA's, and gaps, if any.

Community Composition		
Indicator	**Freshwater Domain**	**Marine/ Nearshore Domain**
Marine Sediment Quality	n/a	Priority Existing Program: Benthos portion of Ecology's marine sediment monitoring Gaps in this program: attrition of regional taxonomic capabilities; no focused spatial coverage for some bays of ecological importance; no capacity to monitor emerging contaminants; no measure of intra-annual variability
Benthic Index of Biotic Integrity (B-IBI)	Priority Existing Programs: Ecology's Status and Trends Monitoring for Watershed Health and Salmon Recovery (WHSR) and Biological Monitoring Program King County's freshwater benthic monitoring programs	n/a

Table 2. Monitoring priorities, existing monitoring programs related to those priorities, and gaps within Toxics in Biota (Signs of Disease) for the marine and freshwater domains. Priorities are organized by species group and compound group. Each species group/compound group has been identified as a priority. For each species group/compound group combination, existing monitoring programs and gaps (if any) are listed.

Toxics in Biota (Signs of Disease)
Macrofaunal Epibenthic Invertebrates (Marine): Priority: PBDE Existing Program: Mussel Watch (NOAA; WDFW; Snohomish County; ENVEST) Gap in program: limited spatial coverage Existing Program: Office of Environmental Health, Safety and Toxicology: Site Assessment and Toxicology Section (DOH) Gaps in program: limited spatial coverage for shrimp and crabs; program for clams discontinued in mid-1990s Priority: Contaminants of Emerging Concern GAP

Toxics in Biota (Signs of Disease)

Marine Pelagic Fish:

Priority: Chlorinated Persistent Compounds (PCBs included in Vital Sign)

Existing Program: WDFW (PSEMP – Toxics in Biota)

Gap in program: Spatial coverage (3 stocks monitored vs. the prescribed 6); temporal coverage (sampled biennially)

Priority: Mercury

Priority Existing Program: WDFW (PSEMP – Toxics in Biota)

Gap in program: Spatial coverage (3 stocks monitored vs. the prescribed 6); temporal coverage (sampled biennially); metals analysis only every 5 years

Priority: Contaminants of Emerging Concern

GAP

Marine Benthic Fish:

Priority: PAHs (Vital Sign)

Existing Program: WDFW (PSEMP – Toxics in Biota)

Gap in program: spatial coverage (e.g., 43 stations have been reduced to 8)

Existing Program: EPA (NCCR)

Gap in program: temporal coverage (only every 5 years)

Priority: Chlorinated Persistent Compounds (PCBs included in Vital Sign)

Existing Program: WDFW (PSEMP – Toxics in Biota)

Gap in program: spatial coverage (e.g., 43 stations have been reduced to 8)

Existing Program: EPA (NCCR)

Gap in program: temporal coverage (only every 5 years)

Priority: PBDEs (Vital Sign)

Existing Program: WDFW (PSEMP – Toxics in Biota)

Gap in program: spatial coverage (e.g., 43 stations have been reduced to 8)

Existing Program: EPA (NCCR)

Gap in program: temporal coverage (only every 5 years)

Priority: Mercury

Existing Program: EPA (NCCR)

Gap in program: temporal coverage (only every 5 years)

Priority: Contaminants of Emerging Concern

GAP

Toxics in Biota (Signs of Disease)

Juvenile Salmon:

Priority: Chlorinated Persistent Compounds (Vital Sign)

Existing Program: Toxics in juvenile salmon by NOAA-NWFSC and WDFW

Gap in program: no full monitoring program funding; limited small scale discovery project to evaluate contaminants in juvenile Chinook salmon underway

Existing Program: Department of Health's Office of Environmental Health, Safety and Toxicology: Site Assessment and Toxicology Section

Gap in program:

Existing Program: King County Lake Washington Studies (sockeye salmon only)

Gap in program: data collection not consistent over time

Priority: Chemicals of Emerging Concern

Existing Program: Toxics in juvenile salmon by NOAA-NWFSC and WDFW

Gap in program: [no full monitoring program funding; limited small scale discovery project to evaluate contaminants in juvenile Chinook salmon underway

Existing Program: Department of Health's Office of Environmental Health, Safety and Toxicology: Site Assessment and Toxicology Section

Gap in program:

Priority: Contaminants of Emerging Concern

GAP

Adult Salmon:

Priority: Chlorinated Persistent Compounds (Vital Sign)

Existing Program: WDFW PSEMP Toxics in Biota

Gap in program: discontinued in 2008

Existing Program: Department of Health's Office of Environmental Health, Safety and Toxicology: Site Assessment and Toxicology Section

Gap in program:

Existing Program: King County Lake Washington Studies (sockeye salmon only)

Gap in program: data collection not consistent over time

Priority: PBDEs (Vital Sign)

Existing Program: WDFW;

Gap in program: discontinued in 2008

Existing Program: Department of Health's Office of Environmental Health, Safety and Toxicology: Site Assessment and Toxicology Section

Gap in program:

Existing Program: King County Lake Washington Studies (sockeye salmon only)

Gap in program: data collection not consistent over time

Priority: Contaminants of Emerging Concern

GAP

Marine Mammals:

Priority: Chlorinated Persistent Compounds

Existing Program: harbor seal monitoring (WDFW: Marine Toxic Contaminants)

Gap in program: other organisms

Priority: PBDEs

Existing Program: harbor seal monitoring (WDFW)

Gap in program: other marine mammals

Priority: Contaminants of Emerging Concern

GAP

Table 3. Monitoring priorities, existing monitoring programs related to those priorities, and gaps within Effects in Biota (Symptoms of Disease) for the marine and freshwater domains. Priorities are shown by species group and measure of exposure (i.e., symptom). Each group has been previously identified as a priority. For each priority group existing monitoring programs and gaps (if any) are listed. The priorities without associated programs are considered gaps. Vital Signs indicates that the priority group has been identified as a Vital Sign indicator by the Puget Sound Partnership and should be a part of continued monitoring.

Effects in Biota (Symptoms of Disease)
Marine Pelagic Fish: Priority: Endocrine Disruption (Vital Sign) Existing Program: None GAP Priority: Vitellogenin Induction Existing Program: None GAP Priority: Other sub-lethal toxic effects Existing Program: None GAP
Marine Benthic Fish: Priority: Endocrine Disruption (Vital Sign – English Sole) Existing Program: None GAP Priority: Vitellogenin Induction Existing Program: NOAA-NWFSC Gap in program: Priority: Liver Disease (Vital Sign) Existing Program: WDFW (English sole) Gap in program: limited spatial coverage Priority: Other sub-lethal toxic effects Existing Program: None GAP
Freshwater Fish: Priority: Endocrine Disruption Existing Program: none GAP Priority: Vitellogenin Induction Existing Program: none GAP Priority: Other sub-lethal toxic effects Existing Program: none GAP
Freshwater Amphibians: Priority: Other sub-lethal toxic effects Existing Program: none GAP

Effects in Biota (Symptoms of Disease)
Juvenile Salmon: Priority: Endocrine Disruption (Vital Sign) Existing Program: none GAP Priority: Other sub-lethal toxic effects Existing Program: none GAP
Adult Salmon: Priority: Prespawn Mortality Existing Program: NOAA - NWFSC Gap in existing program: None Priority: Other sub-lethal toxic effects Existing Program: none GAP
Marine Mammals: Priority: Endocrine Disruption Existing Program: none GAP Priority: Other sub-lethal effects Existing Program: none GAP
Marine Birds: Priority: Other sub-lethal toxic effects Existing Program: USFWS (Pesticides in raptors) Gap in program: no current monitoring Existing program: USGS (PCBs in cormorant eggs; Toxics in heron eggs; Toxics in osprey eggs) Gap in program: no current monitoring

5.2 Chemical and Physical Characteristics – Gaps

Gaps were identified only in the marine domain, and within this domain, gaps were limited to inorganic and organic compounds in sediment (Table 4 and Table 5, respectively). No priority gaps were identified in monitoring contaminants in the water column. Pesticides in freshwater scored relatively high in comparison to other freshwater monitoring activities; however, it was overall lower than other survey results and is thus not identified as a priority or a gap in the tables below.

Table 4. Monitoring priorities, existing monitoring programs related to those priorities, and gaps of Chemical and Physical Characteristics for inorganics in marine sediment. Priorities are listed by location and compound group. Each group has been previously identified as a priority. For each group, existing programs and gaps (if any) are listed

Trace Inorganics in Marine Sediment
Mercury: Priority: Urban Bays Existing Program: Ecology's Marine Sediment Monitoring Program Gap in program: no focused spatial coverage for some urban bays of ecological importance Existing Program: King County Subtidal Sediment Sampling Gap: none Existing program: King County/ Dept of Ecology NPDES permit for King County's South Treatment Plant (NPDES permit WA-002958-1) GAP Existing program: Pierce County/ Dept of Ecology NPDES permit (NPDES permit WAR04-4002) GAP Existing program: King County/ Dept of Ecology NPDES permit for King County's Brightwater Treatment Plant (NPDES permit WA-0032247) GAP Existing program: King County/ Dept of Ecology NPDES permit for King County's West Point Treatment Plant (NPDES permit WA-002918-1) GAP
Other metals: Priority: Urban Bays Existing program: Ecology's Marine Sediment Monitoring Program Gap in program: no focused spatial coverage for some urban bays of ecological importance Existing Program: King County Subtidal Sediment Sampling Gap: none Existing program: King County/ Dept of Ecology NPDES permit for King County's South Treatment Plant (NPDES permit WA-002958-1) GAP Existing program: Pierce County/ Dept of Ecology NPDES permit (NPDES permit WAR04-4002) GAP Existing program: King County/ Dept of Ecology NPDES permit for King County's Brightwater Treatment Plant (NPDES permit WA-0032247) GAP Existing program: King County/ Dept of Ecology NPDES permit for King County's West Point Treatment Plant (NPDES permit WA-002918-1) GAP

Table 5. Monitoring priorities, existing monitoring programs related to those priorities, and gaps of Chemical and Physical Characteristics for organics in sediment. Priorities are listed by location and compound group. Each group has been previously identified as a priority. For each group, existing programs and gaps (if any) are listed. The priorities without an associated program are considered gaps.

Trace Organics in Marine Sediment

PAHs:

Priority: Central Basin

Existing program: Ecology's Marine Sediment Monitoring

GAP: none

Existing program: King County/ Dept of Ecology NPDES permit for King County's South Treatment Plant (NPDES permit WA-002958-1)

GAP

Existing program: Pierce County County/ Dept of Ecology NPDES permit (NPDES permit WAR04-4002)

GAP

Existing program: King County/ Dept of Ecology NPDES permit for King County's Brightwater Treatment Plant (NPDES permit WA-0032247)

GAP

Existing program: King County/ Dept of Ecology NPDES permit for King County's West Point Treatment Plant (NPDES permit WA-002918-1)

GAP

Priority: Urban Bays

Existing program: Ecology's Marine Sediment Monitoring

Gap in program: no focused spatial coverage for some urban bays of ecological importance

Existing program: Pierce County/ Dept of Ecology NPDES permit (NPDES permit WAR04-4002)

GAP

Existing program: King County/ Dept of Ecology NPDES permit for King County's South Treatment Plant (NPDES permit WA-002958-1)

GAP

Existing program: King County/ Dept of Ecology NPDES permit for King County's Brightwater Treatment Plant (NPDES permit WA-0032247)

GAP

Existing program: King County/ Dept of Ecology NPDES permit for King County's West Point Treatment Plant (NPDES permit WA-002918-1)

GAP

Priority: Non-Urban Bays

Existing program: Ecology's Marine Sediment Monitoring

Gap in program: no focused spatial coverage for any non-urban bays of ecological importance

Priority: Puget Sound Wide

Existing program: Ecology's Marine Sediment Monitoring

Gap: none

Chlorinated Persistent Compounds:

Priority: Central Basin

Existing program: Ecology's Marine Sediment Monitoring

Gap in program: not all persistent chlorinated chemicals are analyzed for

Existing program: Pierce County/ Dept of Ecology NPDES permit (NPDES permit WAR04-4002)

GAP

Existing program: King County/ Dept of Ecology NPDES permit for King County's South Treatment Plant (NPDES permit WA-002958-1)

GAP

Existing program: King County/ Dept of Ecology NPDES permit for King County's Brightwater Treatment Plant (NPDES permit WA-0032247)

GAP

Existing program: King County/ Dept of Ecology NPDES permit for King County's West Point Treatment Plant (NPDES permit WA-002918-1)

GAP

Priority: South Puget Sound

Existing program: Ecology's Marine Sediment Monitoring

Gap in program: not all persistent chlorinated chemicals are analyzed for

Priority: Whidbey Basin

Existing program: Ecology's Marine Sediment Monitoring

Gap in program: not all persistent chlorinated chemicals are analyzed for

Priority: Urban Bays

Existing program: Ecology's Marine Sediment Monitoring

Gap in program: no focused spatial coverage for some urban bays of ecological importance, not all persistent chlorinated chemicals are analyzed for

Existing program: Pierce County/ Dept of Ecology NPDES permit (NPDES permit WAR04-4002)

GAP

Existing program: King County/ Dept of Ecology NPDES permit for King County's South Treatment Plant (NPDES permit WA-002958-1)

GAP

Existing program: King County/ Dept of Ecology NPDES permit for King County's Brightwater Treatment Plant (NPDES permit WA-0032247)

GAP

Existing program: King County/ Dept of Ecology NPDES permit for King County's West Point Treatment Plant (NPDES permit WA-002918-1)

GAP

Priority: Non-Urban Bays

Existing program: Ecology's Marine Sediment Monitoring

Gap in program: no focused spatial coverage for non-urban bays of ecological importance, not all persistent chlorinated chemicals are analyzed for

Priority: Puget Sound Wide

Existing program: Ecology's Marine Sediment Monitoring

Gap in program: not all persistent chlorinated chemicals are analyzed for

PBDEs: Priority: Central Basin Existing monitoring program: Ecology's Marine Sediment Monitoring Gap in program: not all PBDEs are analyzed for Existing Program: King County Subtidal Sediment Sampling Gap: none Priority: Urban Bays Existing monitoring program: Ecology's Marine Sediment Monitoring Gap in program: not all PBDEs are analyzed for
Chemicals of Emerging Concern: Priority: Urban Bays Existing monitoring program: Ecology's Marine Sediment Monitoring Gap in program: funding has been sporadic and only selected CECs have been analyzed for in selected locations.

5.3 Ecological Processes – Gaps

The Ecological Process EEA category was not specifically addressed in the survey performed by the TWG. One of its KEAs (Material Transport: accumulation, fate, and transport of contaminants) was identified as an important KEA. As there is no monitoring and limited modeling of this KEA, it is considered a gap. The TWG feels that while this is an important gap, it should be filled once the other gaps are addressed. This is due to the fact that the information gathered in the other monitoring gaps will provide necessary data for this KEA.

5.4 Human Health – Gaps

A specific gap analysis was not performed on monitoring associated with human health and human well-being. However, many of the gaps and programs identified above would provide valuable information for the evaluation of potential impacts to human health.

6 Potential future evaluations/next steps

As mentioned in the introductory paragraphs, we acknowledge that there are many potential purposes of monitoring activities. These may include:

- Characterizing toxic chemical-related aspects of the biophysical condition of the Puget Sound ecosystem
- Characterizing human well-being as affected by toxic chemical contamination of the Puget Sound ecosystem
- Assessing toxic chemical-related pressures on the Puget Sound ecosystem
- Assessing the effects of toxic chemical management efforts, including monitoring assigned to meet statutory or regulatory requirements, and
- Conducting scientific studies to support these other purposes.

The articulation of toxics monitoring priorities and gaps presented in this document is based on our explicit consideration of only the first and last of these purposes. This focus will also provide information useful to for the other three purposes. Next steps for collaborations across PSEMP related to these monitoring purposes are suggested in Section 4.

In our continuing work as a PSEMP workgroup we will extend our evaluations into the other dimensions of toxics monitoring and update our conclusions about monitoring priorities and gaps. For calendar year 2014 we expect to focus on monitoring to assess the effects of management and a more complete evaluation of our priorities for monitoring human health risks and other aspects of human well-being.

We acknowledge that the outcome of any priorities and gaps evaluation that we conduct will be dependent on the particular type of monitoring in question, e.g., the priority list for status and trends monitoring may be different that for evaluating toxics effects. As a result we understand that a key challenge for our continuing work will be to articulate our priorities for monitoring across these purposes (i.e., is it more important to characterize human health risks or to assess effectiveness of management efforts?). As we move into the work of identifying overall priorities we would hope to expand our workgroup focus or convene special events to more fully engage managers and stakeholders concerned with toxic chemical management, protection and recovery of species affected by toxic chemicals, and human health protection.

7 References

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8 Appendices

Appendix A. Inventory of Puget Sound Monitoring Efforts

Appendix B. Evaluation of monitoring gaps related to the Puget Sound Partnership Vital Signs indicators.

Appendix C. Conceptual Models

Appendix D. Monitoring Inventory of Biotic Condition – Freshwater and Marine and Nearshore

Appendix E. Monitoring Inventory of Chemical and Physical Characteristics – Marine and Nearshore, Freshwater, and Terrestrial

Appendix F. PSEMP Toxics Workgroup – Monitoring Priorities Survey: Approach and Results

Appendix G. Mapping of current monitoring activities onto selected KEAs.